MOULD DESIGN AND WORKSHOP PRACTICE

Paper presented to the Institution, Manchester Section, by A. G. Snell.

MOULDS for producing articles in plastic materials have in the past been divided into a number of classes, namely, positive-type moulds, flash-type moulds, and semi-positive moulds. When one considers the vast and varied numbers of articles the industry to-day is called upon to manufacture, I am afraid the above designations do not fully cover the present-day design of moulds.

There are thousands of articles produced in plastic materials which from a mould point of view are repetition work not only to the moulder but to the tool designer. We are more than thankful that this is so, because without this work there would be no plastic industry. Simple tool work usually, but not necessarily, means simple production, and it is the work we almost forget and leave knowing that there is very little that can go astray, a fact that allows us to devote our time to the more complicated and interesting side of the industry and to develop along the rapid lines the past few years have shown. I propose, therefore, to-night, to deal with a few of the difficulties which it has been my lot to surmount.

Moulding a Fireside Kerb.

In considering this type of article as a moulding, great thought had to be given to its design, and care taken that when completed it would be appreciated by the buying public. Models had therefore to be made and approved before any thought could be given to mould design. The question of price of the finished article also had to be very carefully considered because, as you are all aware, you cannot sell an article in great quantities unless the price is right.

In the manufacturing of this fireside kerb a new departure was made in the types of materials used and it was only by the combination of three elements—first, a pleasing shape ; second, a new material ; and last, but by no means least, a tool which could produce the first element by using the second economically and easily that it was possible to put this article on the market to compete with its predecessor in metal and wood. As I am not here to-night to conduct a sales campaign for a proprietary article in which I have an interest I will now give you one or two points it was necessary to consider before manufacturing the mould to produce the fireside kerb.

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The mould was designed to produce one complete kerb, namely, three mouldings in one operation, as any form of extraction by means of pins would have marred the appearance of the finished article. It was essential that when the completed mould was opened the article should remain in that portion of the mould from which in shrinking down it could be removed by hand and without extracting pins. Care had also to be taken to prevent distortion of the articles, which would have been fatal when the three portions of this kerb were assembled. Another important factor was arranging for the quick distribution of the material in the loading of the mould. The material had to be spread evenly but rapidly, otherwise that which was first put in the mould would burn before pressure was applied, giving very inferior finish. Another point which required consideration in the mould design was the elimination of waves or ripples on the surface of the finished articles, a fault which is very general on flat surfaces unless study is given to prevent it in the design of the mould. A great many moulders blame the powder or material for this fault, and while it is often caused by the flow of the material being too free the root of their trouble generally lies in poor mould design. To prevent obtaining this very displeasing appearance you must arrange your mould to give pressure to the walls of the article as well as to the base. This can be arranged by making the material take the full pressure on the last $^1/_{32}$ in. of the closing of the press, which means that the mould becomes a mould when the article is completely formed, though up to that point it is a flash-type mould.

Moulding a Commutator.

I think I have now said enough about this particular type of moulding and will pass on to a small but very interesting article made up of a number of metal inserts and forms of plastic materials, all knit to form one solid job. This commutator has a shock-resisting base, made from a paper-filled material and several rings of wood-filled material incorporated to secure and insulate some metal segments, and a special anti-tracking material to separate the brass studs and to resist the wear of the slider which passes over them at a very high voltage. This moulding has been acknowledged as unique by many old-established members of the industry, and the the use of plastic materials has in this case overcome seemingly insurmountable difficulties experienced in the old and very expensive method of building up from sheets and segments.

The successful moulding of this article required more than good tool design. It involved considerable experimental work and a careful study of the reaction of the various materials to remoulding, as the shock-resisting base has to pass through three pressing operations in the course of manufacture. It was, however, only

by arriving somewhere near the ideal tool design in the early stages that the cost of this experimental work was satisfactory, both from the customers' and the manufacturers' points of view. It is a great pity that many manufacturers fight shy of work which entails an element of risk and uncertainty and the possibility of subsequent loss if the results prove unsuccessful, as in an industry which is only in its 'teens it is everybody's duty to carry a portion of the load, if we are to attain that ultimate success which, as has been prophesied, lies before us. I find I am wandering from my subject and must come back to earth and describe to you the processes entailed to produce this moulding. We must first of all mould our shock-resisting base in which must be carried the recesses and location for our brass rings and segments. After careful gauging, and treatment to ensure the perfect knit of the wood-filled material, we lay in our metals and once more the moulding goes back to the press shop. Here it is placed in another mould and together with the metals actually becomes a plastic insert in a further plastic moulding. The resultant of this second operation then visits the machine shop and is machined out to take the brass studs and the anti-tracking material. Its next and last visit to the moulding department is a very important one as it has by now become a very valuable piece of work and a slight under or over cure of the anti-tracking material scraps not only all the materials but two moulding and two machining operations. It is then finally machined to size and is ready for dispatch. You will notice from these operations that the original moulding passes through two sets of dies apart from the one which first produced it, and when you take into consideration that each of the three materials used possesses different shrinking possibilities, you will realise the importance of the tools being well designed and absolutely accurate.

Moulding Refrigerator Door Framing.

My third and final illustrations are two frames which form the door surround, and the aperture facing, for a refrigerator. Unlike the kerb these mouldings have to be extremely accurate dimensionally, as on this depends the fit and perfect sealing of the door. Their size and delicacy presents a fair problem as it is well known in the industry that there is no constant to determine shrinkage. Shrinkage is a factor dependent on sectional area against the length and nature of the article being moulded, and I defy anyone to take a moulding such as this and give me a dependable allowance. The only method of tackling such a job is to combine experience with common sense and to design the tools in such a way that any discrepancies are on the safe side so to enable the dies to be opened out to the correct dimensions. I do not wish to convey that such tools are made on a trial and error basis, as that is definitely not

so, for if moulds such as these are designed to give good results from a production point of view, the margin of safety left on the tools must be very slight. Very small deviations from drawing sizes on large work can be overcome by varying the flows of the material as very stiff-flowing material has less shrinkage than easy-flowing material. In finally arriving at our correct sizes on these two jobs we had prepared sample batches of powder, carefully graded, having minute differences one from the other, and ran off about 50 articles from each batch until the correct flow was finally decided. The extraction of these mouldings, as in the case of the kerb, had to depend on their reduction in size to free themselves from the outer die, and arrangements had to be made to ensure that they cooled off under ideal conditions to prevent distortion taking place during the cooling. In summing up tool design the following are the vital points to watch :—

Extraction without distortion.
Maintenance of accuracy.
Accessibility to prevent damage to mould.
Foolproof operation of mould.
Correct mould thicknesses to ensure sufficient strength without loss of heat.
Selection of suitable steel.
Discharge of excess material without loss of pressure on moulding.
Elimination of crevices into which the material will eventually find its way, as in built-up moulds , and, finally, a study of the plant that has eventually to carry the mould.

Moulding Shop Procedure.

We will now leave the design of the mould and consider the correct procedure in the use of some moulds and in the subsequent operations in the manufacture of the final product. I will divide these up into the following headings and give a brief survey of each :—

(1) Storage of moulds. (2) Setting up of moulds. (3) The moulding department. (4) The finishing and drilling departments. (5) Polishing of mouldings. (6) Final inspection of mouldings. (7) Progress of work through departments.

(1) When a prospective customer is considering the use of plastic mouldings for the first time he is usually given an unpleasant surprise when informed of the cost of his share of the mould. Moulds if properly constructed are unavoidably expensive, but their expense diminishes when the capability of the mould is considered, always provided that the moulds are carefully kept and maintained. It is, therefore, essential to appoint a keeper for the "Crown Jewels" of our industry and to make him responsible for their maintenance, so that when orders come along for work we had almost forgotten

we can lay our hands on the moulds knowing that they are ready for use. Moulds, unless properly cared for, deteriorate more in storage than in use, and it is our duty to our customers carefully to maintain the property they leave in our possession.

(2) The setting up of the moulds is a very important factor in the smooth running of an industry such as ours. The person responsible for such work must be fully conversant with the moulding operations on each mould he is called upon to set, and must realise the damage which may occur and the slowing up of production which will result if a mould is badly set. He must take full advantage of the daylight on his press, arrange his fixings to eliminate waiting time between orders where similar presses are used, choose suitable platens in order to cut out loss of heat and ensure that it is impossible for loose portions of the mould to be replaced wrongly. When you consider that 500 tons is quite a normal pressure on a large die, it is important to realise what can happen under such pressure if anything is left to chance.

Having considered the care of the tools we will now study their use. This brings us to the basic department of the moulding trade—the moulding department. I have often heard people remark that it is the moulds that count in plastic moulding. They emphasise the word " moulds " as if to say : " make the moulds and you can forget the rest." I say emphatically that in any business everything counts and everybody must play his part and consider it important, from the errand boy to the managing director. Even if that were not so I should still say that the correct running and careful watching of the moulding department are probably our most important items for on it depends our success or failure, the satisfaction of our customers and the easy control of the subsequent operations necessary before any goods leave the works.

The remarks previously mentioned are made because the people from whom they emanate know sufficient of the industry to realise that our goods are produced in the main by semi-skilled operators, but do not understand that this is only possible if skill and experience lies behind them and is constantly watching over them. It is, therefore, essential to have a number of men, according to the size of your business, who can pick up an imperfect moulding and know from its appearance the cause of its defects. It is by the possession of these persons alone that valuable moulds can be worked by semi-skilled men and successful results be obtained.

It is possible for operators to produce work, especially on heavy sections, with a satisfactory external appearance but with a soft core due to insufficient curing. On the other hand, mouldings can be over-cured, but this is less probable if piece-work systems are in operation. By these remarks I have tried to force home that it is essential before pressing commences to ascertain the correct heat

and pressure necessary to obtain the best results, and by careful watch and inspection make certain that these are maintained. It is also a custom in the particular business in which I am interested to retain one or two men who exercise more care and thought than the majority for special work. We find this necessary because we make many complicated mouldings containing inserts and fittings of considerable value in many cases of greater value than the moulding itself less the inserts.

There is an increasing demand nowadays for articles produced from urea material. For decorative work they are far superior to mouldings produced from phenol powders and urea material will eventually entirely replace phenol material so far as the fancy goods trade is concerned, though for utility work the latter product is, of course, much more economical. It is a mistake to try and produce phenol and urea mouldings in one department. Owing to the light colour of urea materials it is fatal to have any contamination even in the air. There is always a certain amount of dust prevalent when moulding in phenol powder and the examination of window frames, etc., even after one week's work proves that the air is loaded with sufficient dust to ruin mouldings in very light powders. It is, therefore, futile for a manufacturer to contemplate producing from both classes of material unless he is prepared to run two departments both suitably equipped for their own particular work.

So much for the moulding department or rather departments. Let us now consider the trimming and drilling of a manufactured article. I personally consider it wise to combine these operations. It is often necessary to trim mouldings before drilling in order that they may be readily fitted into drilling jigs, etc. It is also possible to receive nasty cuts from flash should untrimmed articles rotate with a drill. On the other hand, if drilling can be done before trimming, the drilling scrap does not carry the trimming expense. When these departments are combined much time and money is saved by eliminating excessive handling, and if they are under the control of one man much smoother running is assured, as he will make certain that work required for drilling is ready trimmed and vice versa.

There are many methods of finishing mouldings, their applications being dependent on the nature of the article. The chief are: barrelling, hand filing, filing on a lathe, and emery bobbing. It is sometimes necessary to machine mouldings and where this practice is followed it is advisable to use a special tool material such as "Widia," as owing to the abrasive action of the moulding ordinary high speed steel wears rapidly.

There is little to be said with regard to drilling except that special drills and taps must be used and holes and threads regularly checked

owing to the wear imposed on such tools by synthetic resin mouldings.

It is a mistaken idea amongst users of mouldings that die finish is the ideal final result. A moulding taken from a highly polished die, even if the mould is chromium plated, can be greatly improved by light polishing with a mop. For all except ornamental work, die finish from a well-polished mould is quite satisfactory, but when appearance is the selling factor a light mopping will always give the desired finish. It is only possible to obtain a lasting lustre by ensuring that the mouldings require only light polishing. A poor-finish moulding can be buffed to a high polish, but will soon be affected by the atmosphere and after a day or two's standing will go very dull. It therefore follows that the correct policy is to look after your dies and cut the polishing department down to a minimum.

As with every well-organised business a staff of inspectors is necessary to guard against imperfect work and we must pick our final inspectors with much care and thought.

Good service is another vital factor in the satisfaction of our customers, and in order to ensure this a well organised progress department is an absolute necessity.

In conclusion I should like to thank you for your attention and tolerance ; it has given me great pleasure to talk to you to-night about one of the most fascinating industries that it is possible to be interested in. While it is still very young, I have no doubt as to the future which lies ahead of it, no one dare forecast the use to which synthetic resin materials may be put in the near future, and I think I am right in stating that everybody concerned in the industry has his heart and soul in its progress. There is a feeling apart from the commercial side, that you are helping in the development of a material that is going to play a big part in many spheres of industry in the next few years. Many things before impossible are now accepted facts since its inception and in many cases other industries are entirely dependent on our productions.

Discussion.

Mr. Fraser (Section President): Mr. Snell can perhaps tell us what kind of steel he uses for his moulds. He referred to insulation material. I take it by insulation material is meant material suitable for commutators. Is different powder used for insulation material than for ordinary mouldings. Could Mr. Snell give us the pressures and temperatures for the average moulding ? That might be useful to know. Reference was made to the necessity for cleanliness, particularly with regard to urea moulding? Having had a little experience in that direction I agree. Does Mr. Snell consider a dust-proof room necessary in that particular case ? Mr. Snell has referred to special drills. It would help us considerably if he could give us some idea as to the tool steel used for special drills, their particular shape, or any other helpful information.

Mr. Snell : Regarding the steel that I use, I won't say it is in general use on moulds because I think moulders use almost every steel they can get hold of, but the steel I have found most satisfactory is air-hardening steel, that being satisfactory because it is not costly and can be bought at from 8d. to 9d. a lb. It hardens up to 480 Brinell, a very satisfactory hardness for moulding tools, and keeps its shape very well. There is no distortion during the hardening. It is usually remachined on the surface after a number of mouldings have been made and has a very satisfactory surface. It is also quite satisfactory for chromium plating.

Bakelite and phenol material are generally excellent insulators and there is no difference in the materials from the insulation point of view.

The temperatures used with phenol materials, vary from about 350-400°F. You can go to 500°F. if the mouldings are worked very quickly. Some small mouldings take a minute to cure ; others, five, six, or seven times longer depending on the thickness and the quality of the job. So on a very quick-curing article, where the mould slides in and out of the press, you can keep your presses up to 500°F., but where the mould is fixed to the press, the general temperature is between 350-400°F. On urea material with lighter shades of material, the temperature comes down to about 180-200°F. owing to its colouring.

With these fine light shade powders a dust-proof room would be beneficial. We do feel it is necessary to have separate departments for pressing urea materials and phenol materials.

There are special drills and taps on the market for drilling and tapping bakelite—ordinary fluted drills which release the swarf,

harder than standard drills at the tip only. The majority of tool makers to-day supply them for this particular type of work.

MR. ECKERSLEY: Mr. Fraser has asked the lecturer what material is used for the dies and Mr. Snell has given us a bit of information, but I do not think it is really sufficient. Is it nickel chromium steel that is used? Has stainless steel been tried and with what results? I should like to know a bit more about the technique of die making and how far it parallels with that for white metals. There are certain parallels, I should imagine, such as the use of ejector pins. (I intend this reference to pressure die-casting purely.) Are the moulds pre-heated for use? Are there any specified or known pressures that can be calculated for various kinds of jobs? Mr. Snell mentioned two materials which have been used—one in which cleanliness is necessary and another material for other purposes. I would like to know a little more about those because I know very little about this business. Is there a very great difference in the prices of the raw material?

MR. SNELL: A good number of people are using stainless steel for moulds, but I do not think it can be used generally because of the price. Even if you use it, in the majority of cases you have to have the mould chromium plated to give the finish necessary on some moulds. Therefore it is cheaper to use an air-hardening steel and chromium plate it afterwards. The trade had great difficulties in the past in trying to get people to give satisfactory chromium plating. However, they have got over that difficulty now and I have seen chromium plated tools after alteration has been made to the surface and the tool hardened again, where the chromium remained intact. It is really a waste of money to pay big prices for stainless steel and then have it chromium plated.

Concerning die castings, I would like you to consider that in moulding phenol material it is necessary to use a pressure of from 1 to 2 tons per sq. in. I am afraid that anything but good quality steel would not stand that pressure and produce the quantity of mouldings that we expect from one mould. The moulds must be preheated to temperatures between 350-400°F. before the material will flux and conform to the mould. When it is placed in the mould it is either in tablet form or powder form. If in tablet form it has been pre-formed from the powder. The heat of the mould must be there before you can press a satisfactory moulding. Urea material is approximately 100% dearer than phenol powder.

MR. ECKERSLEY: What is the technique for handling the two materials?

MR. SNELL: Various characteristics of one material are slightly different from those of the other. From an insulation point of view I would say the phenol material is the better.

Regarding conditions under sea water or salt water, urea materials

are better. You can carry out tests to-day to find whether one material has any advantage over the other. Generally, for insulation, phenol material is the more satisfactory.

MR. ECKERSLEY: Can you give us some information relative to the technique of making and designing the moulds particularly with respect to venting cores, and where are cores practicable?

MR. SNELL: It is rather difficult to answer, because almost every moulded article requires an entirely different design of mould. The sound basis is to my mind to machine the form of the article out of a solid blank of steel. It is unnecessary to vent the moulds.

MR. MURRAY: I am wondering whether the steel used in the dies would soften during working. I always thought that the finish of nickel chromium steel could be quite as good as chromium plating and thought that plating was to prevent chemical action. What is the best method of heating moulds? Steam, air, gas, or electricity?

MR. SNELL: Regarding tools losing hardness during working, I have not found that at all. We have some tools at our works that have produced quite two million articles and have been continually on the press for six months, and I have not found that a tool has softened at all during the process. I do not think softening is general because the temperatures used are, say, from 350-500°F., which does not seem to affect the steel at all. If anything, the surface of the mould, due to pressure so many times applied, tends to harden and the tool is in really better condition after having been used for some considerable time than at the beginning.

Regarding heating by electricity, gas, or steam, I think steam is the cheapest. We in our factory are using electricity from this point of view; every press is then a unit. With other methods if we close down a press we would be wasting a certain amount of steam, etc. We can now add presses when we wish without adding to our boiler plant, etc. Generally, steam is considered the cheapest. There is a certain stain comes from urea which reacts on the steel itself under the chromium plating. Chromium plating for general moulding gives a better lustre to the mould and you transfer that lustre to the moulding. That is an added advantage of a chromium plated mould.

MR. F. W. SHAW: As one of the previous speakers said, I have had no experience in the manufacture or even in the use, for business purposes, of these steels, but I have had rather an unfortunate experience in their use for domestic purposes. I should like to ask the lecturer to express some opinion as to why articles such as cups stain with tea, say, and why, if you happen to drop one of them, although they are supposed to be unbreakable, it sometimes breaks very nearly as readily as pot.

MR. SNELL: These things are made simply because they can be sold. Regarding staining, I have heard they do stain—I think you

must have had some very strong tea! This ware is largely sold for picnic fixtures and things like that. There is a very big market for it—approximately six or seven tons of material are sold in that form weekly—and the reason is simply because it can be sold.

A VISITOR: What is the lecturer's experience with mild steel tools case-hardened? Also, what does he suggest is the best powder to eliminate tracking? Also, taking into consideration the finished moulding, is there any known method of testing a new moulding? The mouldin4 may be all right in appearance, the lustre quite good over its surface. Is there any method of testing a moulding for soundness other than by splitting it with a hand saw or subjecting a moulding used in the electric trade to an insulation test.

MR. SNELL: Regarding moulds made from mild steel case-hardened, I do not recommend that practice. From an accuracy point of view it has not proved very satisfactory. The mould that is only case-hardened is likely to creep under continuous pressure or even distort simply because the case only is hardened and the inside core quite soft and not able to resist the pressure as would a better quality of steel. I think that the only advantage you get with a mild steel mould is that it is cheaper to machine. It is cheaper from the steel point of view because if you buy, as I suggest, a harder steel, this probably runs to about 8d. or 9d. a lb. You can get a good quality mild steel at 4d. or 5d. per lb., but you pay extra for case-hardening it. Regarding non-tracking powder, urea is the best. Concerning the testing of a mould, I think there is only one satisfactory way—to use it. You will find, for some reason not understood, the first time you put the tool on a press, you never get a satisfactory moulding. You have to produce a dozen or two dozen mouldings before the mould gets used to the material or the material gets used to the mould.

To a question on testing a moulding for a flaw resulting from faulty powder,

MR. SNELL replied: In manufacturing an article you get a certain amount of variation between one lot of material and another. Test the material by cutting it up and test the section to see if the material is sufficiently cured. If you get a moulding which is soft in the centre due to its not having been cured long enough, you will find a distinctly different colour, and you can definitely smell the carbolic acid in the material in the uncured portion. You cannot tell by the outer surface.

MR. CROOKE: Mr. Murray raised the question of chromium plating, which the lecturer mentioned two or three times. Now the lecturer admits he does have certain troubles. As production engineers we are not interested in a nice piece of work, but we are really human and like to know about other people's troubles. I

do not know anything about plastic moulding and would like to know the snags.

MR. SNELL : With the right type of press, the right type of die, and the right type of powder, there are no snags, but we do not always get, though we have the right type of press, the right type of die—simply because, as I say, our problems vary one from the other. I suppose we meet more snags in the design of a tool than anything.

With the production materials to-day we do not have a lot of trouble. The greatest difficulty is in tool design. We do have difficulty with moulds where inserts are called for, due to the insert being designed incorrectly, so that with pressure, the insert parts or pins distort.

QUESTION : Can you give us any information comparing the physical properties of moulding material with those of metal in general use in engineering.

MR. SNELL : Various properties are given to moulded bakelite, but they vary according to the design of the particular article, so it is very difficult to give you figures. There are figures in my office, I have not got them in my mind, but they do definitely vary according to the design and section of the article into which it is made.

QUESTION : Can you give us any information on the resistance to wear ?

MR. SNELL : Various articles made from bakelite have been found to wear even better than metal, but others have not worn so well. A plunger made from bakelite will work in a bakelite cylinder for a good long time without lubrication at all ; there is hardly any wear on this material. I have in mind that two years back we made a cylinder with 2 in. bore, also a bakelite plunger, the tolerance being 0.0005 in. These were run for six weeks, and when the two parts were taken asunder the only wear on the plunger was 0.001 in. Other articles have not proved so satisfactory. Without a doubt, it is the moulded surface of the material that makes it satisfactory from the wear point of view. The resin seems to come out on to the surface and form a very hard crust. Another article that is made in bakelite is artificial silk spinning bowls. I do not know whether you know much about these. They are approximately of six inch bore, three or four inches deep, and run at 10,000 r.p.m. I know that some in use to-day have been in use for twelve months, continuously running. Here the material has proved very successful, even more so than ebonite.

QUESTION : Does Mr. Snell know anything about the material made by Imperial Chemical Industries, Ltd., from crystals ? Does

he know anything about casting bakelite, and if so, what is its advantage ?

MR. SNELL : Regarding the new I.C.I. material, I think this has only been produced in their laboratory and nobody seems to know a lot about it.

Cast phenol is the natural resin poured into the mould or cast in stick form, and machined up afterwards.

MR. SHAW, JUNR. : One speaker asked for the wearing properties of some of these products and the lecturer, in replying, mentioned spinning pots. I believe the wear-resisting properties of certain of these pots depends on the incorporation on the materials of a lubricant such as graphite. I would also suggest the possibility of producing mouldings from roughly-formed pieces of the compounds by the methods employed in forming articles in metal. I know of instances where people are using moulded materials as bearings for the rollers of steel rolling mills, and they have stood up quite as well to the pressure as ordinary bronze bearings. A few days ago I was at the Exhibition of Art in Industry, and I was struck very much by the tremendous number of products formed of these synthetic materials. One thing I noticed was a lady's powder box cut out from the solid natural material, and an imitation of it in synthetic material. The price of the natural one was £30, and of the other something like 5s. There you have the possibility of placing before the public almost an exact imitation of your finest works of art. But if these products are to sell at a reasonable price you must make them in big quantities, because of the moulding cost. It is possible to make the moulds so that you can produce a few hundreds of a certain article and make them at a reasonably low price by making the mould in such a manner that there is no fancy work and no high polish, and give your polish to the moulding instead of to the mould by buffing.

MR. SNELL : Regarding cheap methods of making moulds, I suppose it is possible if you have sufficient articles of the same size, but it generally happens that they so vary in size that it is very difficult to make one mould control various sizes of articles. We in the moulding industry do not suggest that our moulds are expensive, but a lot of our customers, when we ask for £30 or £40 for a mould, say " But we can get a second-hand motor car for that price." They do not realise that to make these moulds we have to employ very highly-skilled toolmakers, and toolmakers require good wages, and you do not get a lot of tool-making for a shilling.

A number of mouldings can be arranged to make up quite a number of articles, and if you total the cost of the moulding, the complete article comes out more expensive than if you paid extra money for the mould and moulded the article as one part.

A VISITOR : I have been impressed by the remarkable straight-

ness of the samples. I would like to ask the lecturer if he can give any general hints as to how they have been got so straight, as my experience has been that they distort badly when taken out of the moulds. Is there any particular temperature or method of clamping when cooling ? Any general hints for our guidance on the subject would be much appreciated.

MR. SNELL : With regard to these strips, they are made in a two-way mould and when the top tool is released and the mould is opened, you will find that the two mouldings lie in the bottom of the mould and the shrinkage of the material frees them from the walls so that it is only necessary to take them out and lay them on a flat plate. Some moulders use a lot of extraction pins, etc., to extract their mouldings, which then do get distorted, and after being taken from the mould have to be put under clamps or presses to straighten. But this does not give a satisfactory moulding because a stress is set up and at a later date the moulding will go back to the form it took when it came out of the mould. The only satisfactory way of getting a moulding out of a mould without distorting is to arrange the top tool so as to leave a thin flash on the moulding, so that as the top tool leaves it the moulding is left in the bottom. By breaking the flash you release and can take out the moulding without distorting it. Then that moulding will remain as it is for ever, but if you distort it and straighten it, you will find it will go back to the form it had when taken out of the mould, because you set up a certain amount of stress. In designing mouldings it is sometimes essential to have some sections thick and others thin.

QUESTION : I should like to know whether it is expected that the shrinkage of these different sections will be equal, or does one make a tool on the soft side, so as to allow for a little grinding off if the product is not quite true to shape.

MR. SNELL : Different thicknesses of section makes the design of the tool very difficult, because the shrinkage does vary according to the section. If your commercial tolerances do not allow the differences the safest way is to have a certain amount of surplus on your tools which you can remove to get accuracy.

QUESTION : I have a little experience in the manufacture of decorative boards and we use phenol and eurea. My experience is that urea kept in stock changes rapidly. I wonder whether Mr. Snell has found this difficulty, and if so, how he has overcome it. We find it necessary to make tests at least one week before we use it.

MR. SNELL : With urea material we have exactly the same trouble due to this material being kept in store. It seems to stiffen and will not flow as it should, but you can get over that by using greater pressure. It is advisable for people using urea material to keep their stocks low.

MR. HULME : Has Mr. Snell had any experience with automatic

presses on phenol. I saw one at a machine tool exhibition in London which appeared to be working satisfactorily.

MR. SNELL: On some jobs automatic presses are very satisfactory but our particular business is as general moulders, and of course, we must have presses that produce quite a number of different articles. I do not think there is any doubt that if you get a proposition which would occupy a press for a considerable time, that press can be fully automatic. There is nothing against that, but of course, we in the moulding industry are looking to the press manufacturers to show us something that is automatic.

MR. FRASER: No one has referred up to now to the type of press used. It seems that the press is rather an important factor in the manufacture of plastic materials. Perhaps Mr. Snell can give us some idea whether in buying presses he advises any particular specification of accuracy and the like. I understand Mr. Francis Shaw is here to-night and perhaps Mr. Shaw would give us some information on these presses.

MR. SNELL: With regard to the general type of press a favoured press has an overhead ram, underneath extracting ram and two side extracting rams. There are presses on the market with side rams for extracting split tools. Personally, I have not yet seen anything really scientific in press design. I cannot just spot Mr. Shaw, but I would like to hear him tell us if his company has yet put anything on the market or propose to do, which is really going to be a godsend to the moulding manufacturer.

MR. SHAW: I should be very pleased to show anybody a fully automatic press which we have in our works. The call in this country is nil—at least, not for enough to be produced economically. In the United States I understand a number have been sold, but there is nobody here brave enough to instal them. The press has been tried in several works, but there have been no orders for installing.

MECHANICAL LAPPING WITH REFERENCE TO DIESEL FUEL PUMPS.

Paper presented to the Institution, Coventry Section, by S. Player and J. Somers.

WHILST being fully aware of the broadness of the statement, one feels confident that it is quite accurate to state no class of, shall we say, commercial engineering comes within the degree of accuracy, nor is as important as the manufacture of diesel fuel pump and injector parts.

Regardless of respective merits and de-merits in design, the primary reason for success boils down to the degree of accuracy, or, to be correct, degree of inaccuracy, to which the manufacture must be held. This being the case, it is almost impossible to obtain that most desirable state of manufacture, viz., *interchangeability.* You will note " almost " incorporated, as this condition was very nearly approached some short while ago, details of which will be discussed later on.

So much for generalities. The first essential in the manufacture of pump parts must be a selection of suitable steel—a steel that, apart from presenting a good wear-resisting surface when finished, has the additional advantage of being as near distortionless during heat treatment as is possible to obtain. Particularly is this desirable where it is intended to eliminate grinding the bore of the barrel and to substitute lapping straight from the hardened product. During our own experiments, we found K.E.839 material eminently suitable and this type of steel, we believe, is universally adopted in this country. There is, in our own estimation, quite a lot to be said for the use of Nitralloy on this class of work, in view of its excellent wear-resisting surface and its low temperature heat treatment permitting of practically no distortion. This statement, however, is mere conjecture on our part, inasmuch as we have no personal experience with this steel on this particular class of work.

The subject of this discussion is the lapping of diesel pump parts, but we must touch upon such phases as the foregoing, which have a very definite bearing upon the lapping stage. We can, nevertheless, skip over the preliminary operations in the manufacture of injector parts as being straightforward everyday class of work. We can assume, then, that the parts are now in the heat-treated stage and ready for the final operations.

December 12th. 1934.

Taking the plungers first, they should be rough ground on the plunger working surface, and rough and finish ground on all necessary diameters. The working surface may now be finish ground ready for lapping. Here, let it be stressed, that all grinding operations should now have ceased ; in other words, there should be no other grinding operation necessary after lapping, as to do so is courting trouble from heat liable to be generated, resulting in distortion, however slight. Going back to the finishing operation of the plunger diameters, it is as well to point out there should be no let-out in the accuracy to which this operation should be held, on the assumption that is so often met, that the subsequent lapping operation will take care of all troubles and trials. There is, however, one phase that may be emphasised and that is, frequently *finish* and accuracy are considered synonymous. It is not so, and very often the reverse.

In an endeavour to obtain a fine finish, the wheel frequently becomes glazed and has a tendency to follow irregularities in out-of-roundness or such holes or spirals that may be present in the design of the plunger, therefore a free cutting wheel, although leaving a comparatively rough surface, is much preferable and will present less difficulty and permit of a quicker cutting action in the lapping operation.

The plungers are now ready for lapping and this should be accomplished in three stages, as follows :—

(1) Rough mechanical lapping.
(2) Lapping by means of enveloping cylindrical lap.
(3) Finish mechanical lapping.

In the manufacture of most cylindrical parts requiring extreme accuracy and finish, mechanical lapping is more than satisfactory. It may seem strange, therefore, that the old method of using an enveloping lap is introduced. This operation is, shall we say, a safeguard, as a brief study will show. Mechanical lapping, as described a little later, is conducted between two flat surfaces, thus giving virtual line contact. This being the case, whilst it has a tendency, due to the multiplicity of parts being lapped at one time, to correct slight out-of-roundness, there is also a tendency in some instances, to follow it. Mechanical lapping will, however, ensure a dead parallel surface with a finish unobtainable by any other means at present known. Conversely, the old method of lapping by an enveloping lap will, or can, ensure roundness, but is liable, even in the hands of a skilled operator, to give high and low spots along the length of surface ; in other words, not dead parallel. It will, therefore, be readily seen that by a combination of these two methods, an almost perfect job is obtainable.

Before proceeding with the operations it might be desirable, in case everybody is not acquainted with mechanical lapping, to

explain the method by which this is obtained. The machine consists of a stationary upper lap and a rotated lower lap, the laps being usually of cast-iron and having a diameter of approximately 14 in. The width of the lap face is customarily made the same as the length of the work to be lapped, that is, if the length of the plunger to be lapped is 3⅛ in. then the face width of the lap is similarly 3⅛ in. In the centre of the lower lap is arranged a mechanism for driving the workholder. This mechanism is so arranged as to give a retarding action to the workholder and in operation has the effect of giving a reciprocating movement to the work in the holder. The workholder itself will accommodate a varying number of pieces depending, naturally, upon the size. In the case of the work under discussion this would be some 40 or 50 plungers. The work is disposed in a tangent in the holder in order to create a shearing action when the work is being lapped. With the holder in position, a mixture of abrasive is smeared over the surface of the work, the upper lap is then lowered until it rests on the work and the machine is then set in motion. A combined rotary and reciprocating movement is then given to the work.

The actual time for the operation depends upon the amount of stock to be removed and varies with the size and nature of the work being lapped. Time, however, is the best basis in ascertaining how much stock has been removed. After a definite period has been run the machine may be stopped and one or more pieces examined for size and finish. The time per workholder is comparatively slow, however, inasmuch as the work is being performed on a multiplicity of pieces, the time per piece is relatively fast. It has a further advantage also, that by doing multiples at a slow rate, the fact of slightly running over the time specified has no appreciable effect upon the size of the work.

Reverting to the actual operation, the abrading medium for rough lapping is a mixture of floured Turkish emery or similar abrasive with a suitable amount of kerosene. In our own Diesel lapping, we found that on account of its freedom from impurities, a very suitable abradent was M.303 or M.304.

The rough lapping should be continued until the parts are clean of grinding marks, and this should be accomplished in five minutes actual running time. The plungers should then be cleaned from loose abrasive, and the second stage of lapping proceeded with, by using a split enveloping lap about ⅝ in. long. The same, or similar, abrasive could be used, but sparingly. It is only abrasive which becomes embedded in the lapping medium that is useful. The lap should fit snugly round the plunger diameter and should be rubbed up and down the plunger surface, when rotated. The time should not take longer than a minute actual running. As before stated, this operation is only a precaution against out-of-roundness, and

as such no inspection or examination is necessary afterwards. The plungers can now be reloaded for the final lapping operation. It is preferable to have a separate machine for this in order that the laps should be such a finish as to quickly impart the desired surface on the work. However, if the roughing machine is used, then loose abrasive should be washed off, and a mixture of rouge and kerosene used for the lapping. The machine can be set in action and the operation continued until the desired finish and size are obtained.

Regarding size, this point will be discussed towards the end. The plungers should then be carefully cleaned from all abrading matter, and racked for mating with the barrels.

So much for the plungers. We now come to the barrels, a very different lapping problem. Being associated with a firm of lapping machine manufacturers, it is surprising how disheartening it can be, after discoursing on the lapping of plungers, the prospect so gleefully says: " Ah, but what about the hole lapping ? " and feels he has scored well. So he has for that matter, but present developments may alter all that. At the moment, internal lapping remains much as it was, and always has been, dependent to an appreciable extent upon the skill of the operator.

As stated previously, two methods are in vogue, one to take the barrels straight from the heat-treatment, or to allow of a grinding operation before lapping. Our own experience leads us to believe the latter method to be more desirable, inasmuch as the grinding operation eliminates such heat-treatment distortion as may have occurred. Incidentally, here again, it is advisable to complete all grinding operations prior to lapping ; in fact it is preferable, where possible, to at least rough, if not finish grind, the outside diameters before lapping, in order that stress shall be relieved beforehand. The laps for the bores can be made from various kinds of metals amongst which may be mentioned cast-iron, brass, copper, and lead. If the bore is sufficiently large, cast-iron is probably the best, in view of its maintaining its shape much better than the softer metals mentioned. The lap should be split and mounted for expanding purposes on a taper mandrel. The lap length should be approximately one-half the length of the bore to be lapped. This length is a fair average, bearing in mind the longer the lap the more tendency to bell-mouthing, and the shorter the lap the more liability towards increasing the centre diameter of the bore. The abradent used is similar to that specified earlier, also the same remark regarding the use of too much abrasive equally applies in the lapping of bore. In operation the lap should at all times fill the bore being lapped, greater lapping dwell being permitted where the bore feels tightest in the lap. Roughing and finishing operations similar to those performed on the plungers are recommended. This brings us to the question of sizing and mating.

Here again, there are two ways in which this may be accomplished. The plungers can be made to, say, a basic size of .250 in. and an assortment of sizes taken ranging from —.0002 in. to +.0002 in. in increments of .00005 in. The bores can then be opened to suit selected plungers. The other way, and the procedure which we adopted, was to lap the bores to a satisfactory finish and parallelism, endeavouring to stay within the tolerance of + and —.0002 in., but ceasing the lapping operation, regardless of size, when satisfactory from an appearance point of view. The plungers were then lapped on the lapping machine and picked off as and when they became a satisfactory mating fit with a body. If you will recall, reference was made to " interchangeability " earlier in this discussion. What actually happened in our own experiments was that we obtained some 75% degree of interchangeability and the remaining 25% was handled in the fashion described. To obtain this percentage of interchangeability, entailed comparatively heavy gauging cost for which, however, we were amply repaid by the facilities in the manufacture of the actual components.

We had ascertained from tests that the maximum clearance permissible on the particular design we were working upon, between the plunger and bore of the barrel, was .00003 in. Any greater clearance in the mating fit resulted in the unit being inefficient. It therefore resolved itself into the problem of being able to hold the barrels within this degree of inaccuracy.

A series of three gauges was made, each series having a tolerance of standard on the " Go " and +.00003 in. on the " Nogo." The next series was +.00003 in. on the " Go " and on the " Nogo " +.00006 in., the last series being +.00006 in. on the " Go " and +.00009 in. on the " Nogo." The gauges were, of course, lapped to as close a degree of finish and accuracy as was possible, and in sufficient quantities to permit of as frequent replacements as desirable. Obviously, the life of a gauge when endeavouring to hold work to such close tolerances, was exceedingly short.

It may seem to you that it is rather a tall statement to claim that it is possible to limit gauge to such a close tolerance. It is, however, surprising, given refined finish such as lapping will give, what a small amount can be detected by, shall we say, feel of fit. The surfaces, of course, must be dry and clean, and this being the case it will be found that the bore can feel very slack on the " Go " end of an internal limit gauge made to the tolerances just described, and be a comparatively tight fit on the " Nogo." It should, of course, be borne in mind that when one speaks of a definite " Nogo " in the case of this amount of tolerance, it resolves itself more into a question of definite increase of " feel " rather than " Nogo." This being the case, the components were segregated into the three classes or sizes specified, viz., those falling within the " low,"

"medium," and "high" range of .00003 in. The plungers were then lapped in batches to correspond with these sizes and, as before stated, a very considerable degree of interchangeability obtained.

It may be of interest to give you a brief resume of mechanical lapping from its early days to the present time, touching upon various interesting points which arose during that period. Both the authors of this paper were pioneers in this respect in so far as commercial mechanical lapping is concerned. Although it originally commenced in the United States some twelve years ago, it is somewhat gratifying to know that Britishers were the originators. Our first machine design was a cylindrical lapping machine very similar to that previously described.

Our first outlet was the field of piston pin lapping. At that time loose abrasive and cast iron laps only were used, superseded to-day by bonded abrasive giving a cleaner and quicker job. The result, however, was the same, and manufacturers both there and here were quick to find vast economies both from an improved product and ease of assembly. To those who are acquainted with the accuracy to which modern piston pins are held, a moment's re-reflection will show that to-day the average pin is every bit as accurate as was a gauge not many years ago, and this at practically no additional cost.

The next demand, mainly from the automotive trade, was for suitable lapping equipment to refine the general accuracy and finish of the thickness of piston rings, and this led us, in turn, to developing a flat lapping machine. Here again, after considerable vogue, the bonded abrasive has taken the place of cast iron laps and loose abrasive. Flat lapping presented many more problems than did cylindrical. Several factors entered the succes of flat lapping, viz., the maintenance of flat faces to the laps (without which accurate work cannot be produced). It was necessary to impart a motion to the work, which, whilst enabling the maximum cutting action, still equally distributed such wear as must inevitably take place. As far as the cast-iron lapping machine was and is concerned, a planetary motion was found to be by far the most satisfactory, the gearing being so arranged that this path criss-crossed itself many times before eventually commencing the cycle once again. The result was an almost universal adoption of mechanical lapping in the engineering industry, the satisfactory application of which is illustrated by the following two instances :—

The very excessive cost of making or purchasing plug gauges, led one large motor car firm in the United States to appoint a first-class gauge inspector to conduct tests to enable them to find a solution not only from a cost point but to obtain greater efficiency. Three suppliers were approached and a quantity of gauges purchased from each. All three were supplied of the same steel, the same heat

treatment, and only differed in the surface finish. No. 1 supplied gauges carefully finish ground to size. No. 2 gauges finished by hand lapping using the old type of enveloping ring lap. No. 3 supplied gauges finished by mechanical lapping. The gauges were carefully checked when received and all passed for size, being within standard and .0001 in. of the size called for. The gauges were then put in production and each checked 6,000 holes. Upon being re-inspected it was found the finish ground gauge was hopelessly under size, the hand lapped gauge had lost .00065 in. at front, .00028 in. in centre, and .00012 in. at the back. The mechanically lapped gauge lost .0002 in. at front, .00002 in. in centre, and nothing at back. Surface finish was the governing factor, the report and microphotographs showing that the smoothness and uniformity of machine lapping was the deciding point in the wear and life of the gauge.

Another instance was the problem of successfully lapping components of geared pumps in metering rayon, both from the point of view of price and accuracy. In the early days these pumps were made without very many experiments, but due to breakdowns and the need for exact metering from each pump, one New England manufacturer decided that to obtain the required results, pumps had to be made to the closest limits of inaccuracy. To-day, by the use of modern mechanical lapping machines, he is producing pumps commercially to limits well within .0001 in.

The side plates are lapped on the required face to a high degree of flatness, the distance plates are on both sides lapped to a close degree of accuracy, and the thickness of the gears running between are lapped to a definite clearance fit of .0001 in. This particular manufacturer claims, and undoubtedly obtains, absolute interchangeability, and furthermore, guarantees, providing all pumps are used under the same temperature conditions, exactitude of metering. Without the facilities of mechanical lapping, such a performance would be well-nigh impossible, or at least, the cost would be prohibitive.

Similar conditions apply to the manufacture of oil burner pumps, and other types demanding a close degree of accuracy, compressors for refrigerator parts, glass lapping, hair clipper blades, in fact the field to-day is almost unlimited.

Discussion.

MR. RYDER: Would you place lead in the abrasives? Not so long ago I struck some parts calling for lead lapping. The point in question is on ball bearing grooves and inner and outer members of clutches. It calls for a very high finish and very accurate limits. This lead lapping does not appear to fall into line with mechanical lapping and seems more or less to rely on the skill of the operator. Would you include lead among the abrasives?

MR. SOMERS: No. Lead is a bond for the abrasives. I should not consider it as an abrasive. I should not have thought it would have any abrasive action at all, although it makes a very good bond for abrasive. We do not like it because it has a tendency to lose its shape. It is only used as a medium for carrying abrasives.

MR. STOKES: As far as I know a good many plungers have projections on them which I should imagine interfere if you apply cylindrical lapping.

MR. SOMERS: With two diameter plug lapping, unless there is a fairly wide tolerance it is hardly a subject for mechanical lapping. If the tolerance is high you can quite easily do it on the grinding machine. Lapping gives you a refined finish and strength. It will not make the discrepancy between the work any greater than it is when it comes to the lapper. On the other hand, when you speak of projections, on the Diesel pump these usually occur on one end. There is a minimum of $\frac{1}{8}$ in. between the actual working surfaces and the shoulder and they can rotate outside the lap, or, if necessary, the groove cut in the lap and it doesn't materially bother it.

MR. SINCLAIR: You speak of the use of abrasives and the type of abrasives, but in the question of obtaining a very fine finish to the bore you mention the question of reciprocation in order to obtain the desired finish. What is the specific relationship between the reciprocation and the speed of the lap? I should like some information as to the speed at which the parts actually rotate. Regarding the question of the enveloping lap and the actual sizing of the lap itself prior to its employment for the duty it has to perform, it must bear a certain relationship to the product it has to work.

MR. SOMERS: I don't know that I have ever particularly considered it myself. It comes into the skill of the operator that I spoke about. In general the oscillation could be about one-third the speed of the work being lapped. In other words, it is desirable to get one revolution for every third oscillation—that is speaking from experience. That any actual data is obtained on it I would not like to say. The sense and skill of the operator has to be brought to the job. As regards the second point, we usually commence

this fashion. The lap is tightened sufficiently to where it can just be rotated by hand. The machine is run at a speed that will not cause excessive heat. If it does cause excessive heat we figure it is running too fast, and when this is so we drop the speed of the work. The question of the diameter of the lap. I have had experience in using hard copper lap in which it was found that if you use a split lap to commence and then you find you have to continue the lap operation to get the lapping fit, there is a tendency for the lap to have got out of shape under actual lapping conditions.

When considering the life for an enveloping lap in 75 out of 100 cases the plungers would be perfectly all right had they not seen the enveloping lap. The best proposition seemed to be to put an unskilled man on the job and let him rub these up and down so many times, and so long as the plungers had been through that operation they were considered to be all right for roundness, though, even, in perhaps 75% of cases the plunger is perfectly round before.

A VISITOR: What relation has the length of the barrel on the actual lapping operation? What is the effect of a very large diameter of bore in the barrel and is there a tendency for the abrasive to accumulate?

MR. SOMERS: An average length is three-quarters the length of the work, but that is an average only, and the length is undoubtedly governed by conditions. If there are considerable ports in the centre then obviously the lap needs to be of an additional length because you will have to go back for the grinding. In a case like that it would probably be advisable to put seven-eighths the length of the work. You must consider the design before answering a question like that.

Regarding the amount of superfluous abrasive, the less abrasive you use, within reason, the better. If you can get the abrasive into your lap and have no free abrasive, then there is not much room for abrasive to collect in the ports. To use too much is a common fault with operators. The more abrasive they get on the better they like it and the better it looks, but it may actually be no better than when they started. A good time ago I saw some tappet liners being lapped out in the bore. The operator had a lap which I should say was about 15 thous. longer than the lap he was endeavouring to do. He was using a teaspoon to spoon up the abrasive and the whole operation was totally wasted. Yet, as I say, there is still a feeling with a lot of men that the more abrasive they use the better.

As regards the relation of the barrel to the bore, say, in 6 in. dia. bore, I should not want the lap much longer than $1\frac{3}{4}$ and then I should consider it was quite a ticklish enough job. About 3 in. is the maximum and then it becomes a grinding problem as well. Mr. Player was saying that in some of the tests he undertook for a firm, in endeavouring to eliminate the lapping, he afterwards

reamed a ball broach and made very good class holder. That was in an endeavour to eliminate or at least to minimise lapping. On Diesel Pump work you go to just about the finest you possibly can. Gauge-making is nothing compared with it. On forcing the ball through you may encounter projections. It is difficult when you have ports in it. Any irregularities on the outside surfaces would weaken the structure and the metal would flow and would go through the hole.

Work that we carried out was only experimental. We went right through the development stage, the manufacture of the component, to a definite performance, and beyond that we did not go. Otherwise, we had quite enough troubles in getting so far. Actually we only make the parts of the pump.

MR. SINCLAIR : Within certain limits of experience with this type of lap, I have found a tendency for it to be necessary actually to lap a bore which is approximately 22% longer than the bore actually required, owing to bell-mouthing. In spite of endeavours to overcome this, it is possible to use such a bore and you are only able to get right up to the bore by grinding, that is speaking of 5.1/2 mm.

MR. SOMERS : That is the tendency in any lap, and that is one way to cure it. I have tried that way myself, but I got into so much difficulty through heat generation that I found it was far better to endeavour to train operators to be skilled on that particular lapping operation and by varying the length and the amount of reciprocation we get it, in other words, the amount they cam out of the bore. I found that the best way to overcome bell-mouthing. You get the same proposition with grinding. If you continually cam out of the bore you get the bell-mouthed hole and with hand-operated internal grinders it boils down to how far the operator shall cam out and how far he shall cam over the wheel.

MR. PLAYER : If you will be sure you only have the minimum amount left in for grinding after heat-treating, you get a much better hole. Some time ago the Excello Co. were grinding some holes 2 in. long, about $^1/_{32}$ in. diameter, guaranteeing them within two ten thousandths. That is a long hole, and they told me that it didn't matter what grinding machine they put the work on or what grinding spindle they used. The accuracy of the hole depends upon the preparatory work—in the drilling and reaming of the holes before they heat treat them. In general you will find that if you are particular in the work that you will do before you give it to the grinding machine you will get much better results.

Also with regard to the question of bell mouthing in hand-lapping, I think that is sometimes caused by the defective lap. We put an expanding mandrell on and that lap has a tendency to get two or three ten thousands more at one rod than the other. The mechanic gets his workpiece with the hole, turns it round and puts

it on again, and the irregularity in the lap has a tendency to make the hole larger, and the ordinary man is not particular whether his lap is dead parallel if he knocks it up and does it. It goes over, we know, but he doesn't check it over to see whether it is dead parallel. That will give you a bell-mouthed hole. Or again, we had a man, very skilled, and when I have checked off some of these laps I have been astounded at the shape of them when he was trying to get parallel holes.

Talking about parallel laps, I made some plugs and holes for a certain firm and it was the rottonest job I ever did in my life. I made them by using an ordinary sewing needle and you can tell the size of the lap. This firm said they had never before been able to get a man to do them in this country. They had always been to Germany for them. However, we did them—and they must have lasted very well because we have never had a repeat order for them —I'm glad to say.

MR. RUNTING : I'm sorry, but we have had another order from them for the same thing just recently.

MR. PLAYER : Well they must still have been satisfied or they wouldn't reorder. However, we did make a mechanical machine —we have two on the market. Cammell had one and Kellers the other. It was made automatic and we made the machine work perfectly. For Diesel pump work the lap is just as critical as a plunger.

MR. RUNTING : With regard to the machines mentioned, it is one thing to attempt mechanically to lap a bore of fairly liberal proportions such as these were, and another to straight lap a 6 mm. dia. bore about 2 in. long. You probably now have tolerance enough merely to lap, regardless of parallelism, but with a bore of such proportions and length the trouble is to get it dead parallel. We are developing a machine for that. We are trying to make it, if possible, " feel " the hole as the operator " feels " the hole, tight in a certain spot. We are lapping 1 in. long rollers now, the smallest diameter of which is $^{3}/_{16}$ in. We hold them within 1/2 ten thousa., but even that is not anywhere near good enough for the articles we have discussed to-night.

MR. HOUD : Could you give us any indication as to how long the degree of accuracy is maintained in the pumps themselves. I am the production manager of a firm producing Diesels and I would like to know, if we obtain three ten thous. accuracy, how long do you think this accuracy is maintained in actual service ? Is it maintained over a reasonable period, and, if not, aren't we striving after an accuracy which isn't of much importance ? You mentioned the case of some gauges where the wear is most noticeable after 15,000 times used.

MR. SOMERS : We have a gauge. That gauge is in the hands

maybe of a good operator, maybe not. What it is gauging we don't know—whether it is hard or soft. If it is the latter, it is going to be a lap itself, so that it is tending to wear the gauge itself right from the start. If on gauge operation this wears slow. Apart from that there is always a certain amount of abrasive matter left in the hole.

You do start up with two rather good conditions. You have accuracy to start with. You have two surfaces refined as well as you possibly know how, and whilst you would not call fuel oil a particularly good lubricant, there are worse. There is another factor, too, and that is the plunger length and the barrel length. All are helping to maintain the size you started with. I think the accuracy would be maintained for quite an appreciable time.

Mr. Runting: The actual fact is so. By two lap surfaces dropping together you have taken your friction away. If you reduce your friction you must have got the result you are after. When we first introduced lapping business in America many firms laughed at us. One firm had been grinding piston pins on a Brown Sharpe machine, and when we showed them a lapped pin they said, "Yes, it looks very pretty." We put a ground pin under the microscope. It looked like the sea—all hills and hollows; then, to show them lapping makes a difference, we put a lapped pin under the microscope. The firm's buyer looked at it and said "Wait. I'll be back in a moment." He wasn't back in a moment; he was away half-an-hour, but when he came back he brought the order with him.

Mr. Somers: Don't you think the answer to that question is that it would fail to function when it lost much of its accuracy?

Mr. Runing: Talking about a round bore, a firm who have a plant in New England say they have tried all over America to get this new pump, as these pumps will stand up over months and months, whereas the previous pumps—made to the same design but just ground finish—lasted no longer than 3—6 weeks.

Mr. Houd: What precautions do they take in order to get this accuracy in cutting teeth?

Mr. Somers: I don't know—They don't tell us.

Mr. Sinclair: With regard to the length of life, a fair indication of the leakage can be obtained. If the lap becomes excessive it reduces delivery. At high speed that is not the case. The slowing up of the delivery speed curve gives some indication of the leakage.

Mr. Somers: That is so, because graphs I have here show it, although the data was compiled from new plungers. They do show the difference between a good-fitting plunger and a bad-fitting plunger.

Mr. Sinclair: Also, is there any more accurate means of running the feed?

Mr. Somers: Not that I know.

A Member: With regard to fuel oil; I have been conducting an experiment embodying a test of 100 hours running. We were using the same oil time and time again and at the end of 100 hours the oil was almost entirely de-natured.

Mr. Somers: It loses its lubricating qualities in the course of the run.

A Visitor: Have you any experience of diamond lapping, and has it any advantages?

Mr. Somers: We have no experience of diamond lapping. It would be the same except, probably, better. It is used as a bond and impregnated with emery; you get diamond dust which, of course, is faster.

A Visitor: Is there any advantage as regards taking more off—or finish?

Mr. Somers: It certainly would cut faster and the finish is equally as good, though I doubt whether it would be better. You could take a rough lap and then finish it off all as one operation.

Mr. Runting: The diamond lapping I have seen is used for cutting tools, tungsten carbide, and in watch-making. I don't think it would be practicable for commercial use.

We were working along these lines several years ago. We got out an abrasive which we tried to bond with copper. We succeeded in obtaining it and made a satisfactory lap, but we sold our rights to The Norton Co., and they shelved it. We succeeded in lapping 20,000 crankshafts without the laps showing any appreciable wear. We didn't use diamond dust, but we were after the same result.

A Member: What about cap lapping—eccentricities in the bore—on internal work?

Mr. Somers: We have done nothing on that. We have not had the problem put up to us, but it seems to be bristling with difficulties.

A Member: In connection with the actual cylinder of a pump, can you give me any information as to whether there has been any indication of diamond lapping, where the ball ended diamond is mounted and the actual steel rotated? By fine graduations of speed control the centrifugal force is impressed upon the wall of the bore. This method provides a high finish and extreme accuracy is obtained.

Mr. Somers: Off-hand, I should say you would not get it as accurate as a lap "feeling" a hole. We have found that where you get contact it has to be a bad hole to start with. I don't believe it would correct an out-of-round hole.

Mr. Runting: The variation of the speed can be so managed that it is possible in fact to start lapping the bore with no contact, so that by greatly increasing the speed you would hit the high spot

and then obtain a fine finish throughout the bore. The process is a very long one but very interesting.

MR. DRANE: In that case, if you had a very long lap, point contact would do it, but I don't think a wide lap would do it. If you taper from the point contact I don't think the idea would work.

QUESTION: How much do you leave on for the lapping operation as a whole?

MR. SOMERS: We have usually left on 3 to 4 ten thous., although it depends upon the condition of the grinding. We don't advocate a fine finish although we don't want it rough. Burnishing a job before lapping doesn't do much good. The bore might need 1 or 2 thous. when the lap has half done its work. There still seems to be a few thous. more to come out.

THE CHAIRMAN: There are the four operations I think; finishing, grinding, lapping, and final lapping. What is the amount to start with? With the rough grinding, how much does that operation remove, how much for finish grinding, and how much is left for the final lapping?

MR. SOMERS: Taking right from the grinding stage, in our own production we left on 3 to 4 ten thous. in the first stage, i.e., rough ground job, 3 to 4 ten thous. on the finish ground product, for the first stage of lapping. We cleaned up then. This might take 2 or 3 ten thous. out. The enveloping lapping operation was then started on; then, of course, there was probably no difference in size after the enveloping lap, and the finishing operation carried on until they became either a mating fit in the first method of manufacture or they came down to those three graded sizes.

MR. RUNTING: We sold Pratts six machines on which girls do the operation of rough lapping for wheels. They segregate these six machines: two for first finishing, two for second finishing, and two for final. The wheels are very carefully prepared, not scraped, then they are taken off the machines and the blocks go to the final polishing. They are very carefully cleaned of all particles of abrasive. They use fixing for cleaning off the previous operation. The finished blocks are put into the machine and the girls are trained to lift the top lap up and co-mingle them. They don't take off probably a 200-thousandth part of an inch. Eventually they get them to the exact size. They claim they lap them within a million.

THE CHAIRMAN: Could you give us the speed of the laps—mechanically lapping?

MR. SOMERS: We have a rough range of speeds. We find no advantage in varying the speed over a given range. There also does not appear to be much advantage in altering the speed from $^3/_{16}$ in., diameter work, up to 1 in. In cylindrical work there is really

not much advantage in varying the speed from a material point of view. It does not of necessity mean to say that because you speed the machine up the resulting operation is quicker. Whether that is on account of some of the abrasive that you require being rapidly thrown off or not we don't know, but there seems to be no advantage. The only time we slow down is if we are up against size very very closely, and in the case of Diesel pump work we like to run slower than usual on account of having heads on the end. As a rough average 50 mm. on the lower lap is found to be most satisfactory. We may go down to 35, the very slowest, and 65 mm. the highest. A range of 35 to 65 with an average of about 45, this will probably cover 99.9%.

A MEMBER: In the work carriers for the mechanical lappers, is there any best angle in which to put the heads to mount the cylinders in?

MR. SOMERS: Yes. The greatest circle that a tangent at which the work will rotate and not slip, i.e., the more tangent you can afford the greater the sizing action, but in the case of shoulder work you are up against the proposition of the shoulders being up against the outside of the lap.

On the motion of Mr. Cole a cordial vote of thanks to Mr. Player, Mr. Somers, and Mr. Runting was adopted.

ANNUAL REPORT

and

ACCOUNTS

For the Year ended 30th June, 1935

To be presented at the

ANNUAL GENERAL MEETING,

15th November, 1935,

Holborn Restaurant, London,

at 6-30 p.m.

THE INSTITUTION OF PRODUCTION ENGINEERS.

Balance Sheet as at 30 June, 1935.

Liabilities.				£	s.	d.
Sundry Creditors				155	18	8
Subscriptions received in advance				49	16	0
Sir Herbert Austin Prize Fund				52	10	0
Building Fund				156	5	0
Income and Expenditure Account :						
Balance at 1 July, 1934	£1276	5	7			
Add Excess of Income over Expenditure for the year	322	5	4			
				1598	10	11

Assets.				£	s.	d.
Furniture, Fittings, and Plant at cost less amount written off :						
Balance at 1 July, 1934	£96	11	4			
Additions during the year	156	18	0			
	253	9	4			
Less amount written off	43	15	1			
				209	14	3
Investments at cost :						
£1783 0s. 11d. 2½ per cent. Consolidated Stock				1309	16	2
(Market Value £1515 11s. 10d.)						
Sundry Debtors				158	10	7
Subscriptions in Arrear, *not valued*.						

				Cash :						
				At Bank	326	15	11			
				In hand	8	3	8			
								334	19	7
	£2,013	0	7					£2013	0	7

Auditors' Report.—We have audited the above Balance Sheet dated the 30th June, 1935, and we have obtained all the information and explanations we have required. In our opinion such Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Institution's affairs according to the best of our information and the explanations given us and as shown by the books of the Institution.

34-36, Oxford Street, London, W.1.
17th September, 1935.

(*Signed*) C. H. Appleby and Company, Auditors.
Chartered Accountants.

(*Signed*) Walter G. Kent, *President, Chairman, Finance Committee.*
(*Signed*) Thos. Fraser, *Chairman of Council.*
(*Signed*) R. Hazleton, *General Secretary and Treasurer.*

THE INSTITUTION OF PRODUCTION ENGINEERS.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 30 JUNE, 1935.

DR.

	£	s.	d.
To Salaries...	836	1	9
,, Rent, Lighting, Heating, and Cleaning	203	5	3
,, Local Section Expenses	342	17	1
,, Printing, Postage, Stationery, Telephone, and Certificates	271	14	9
,, Printing, Postages, and Stationery—Journal and Bulletin	543	19	11
,, Staff Travelling and Expenses of General Meetings	84	8	6
,, Professional Charges, Insurances, and Income Tax	44	14	5

CR.

							£	s.	d.
By Subscriptions received :									
Current...				£2020	8	0			
Arrears...	118	4	0						
Less incl. 1933-34	70	0	0						
				48	4	0			
							2068	12	0
,, Interest on Investments							43	6	7
,, Receipts from Sales and Advertisements of Journal							667	2	4

	£	s.	d.		£	s.	d.
„ Library...	24	13	3				
„ Examinations	26	14	0				
„ Annual Dinner, less receipts	9	5	3				
„ Donation to Sixth International Management Congress	10	10	0				
„ Miscellaneous	14	16	4				
„ Amount written off Furniture, Fittings, and Plant...	43	15	1				
„ Balance, being Excess of Income over Expenditure	322	5	4				
	£2779	0	11		£2779	0	11

ANNUAL REPORT FOR 1934-35.

To be presented by the Council to the Annual General Meeting, London, 15th November, 1935.

Membership.

The membership at the end of June, 1935, was as follows :—

Honorary Members	3
Ordinary Members	476
Associates	32
Associate Members	487
Graduates	153
Affiliates	14
	1,165

One hundred and eighty-one new members were added to the Register during the year. Seven members died, nine resigned, and twenty-two lapsed. The Institution suffered a severe loss in the death of Mr. R. H. Hutchinson in March. A Special Committee has been appointed to suggest a suitable memorial to him. The other members whose death has to be recorded with regret were : Messrs. V. V. Ashworth, R. Ewing, A. G. Lemon, C. M. Maxwell, T. E. Pattinson, and E. J. Wiley. Although Mr. J. H. Garnett has died since the close of the year ending June 30th, the Council takes this opportunity of placing on record its sympathy with his relatives and with the Birmingham Section on the loss of their Section President.

Finance.

The annual accounts again show a satisfactory balance. The Chairman of Council for the time being in office has been appointed to succeed the late Mr. Hutchinson as trustee with Mr. J. A. Hannay.

New Institution Headquarters.

On January 1st, 1935, the Headquarters of the Institution were moved from 40, Great James Street to British Industries House, Marble Arch. Not only have good office premises been secured, but there is also available to members a comfortable Club and a Restaurant, as well as improved facilities for lecture meetings.

New Local Sections.

The policy of developing new Local Sections, referred to in last year's report, has been continued. New Sections were opened during the year at Southampton, Leicester, and Edinburgh, and initial steps were taken at Newcastle. In addition a new Graduate Section for London was formed. Further expansion on the same lines during the coming year is being planned, including a new Section at Preston.

Sir Herbert Austin Prize.

The winner of the Sir Herbert Austin Prize for 1935 was Mr. J. Silver, Birmingham.

Medal for Best Paper.

Mr. E. J. H. Jones, Member of Council, London, was awarded the medal for the best paper by a member during the previous session.

Graduateship Examination.

The first examination under the revised and enlarged Syllabus, held in April, 1935, provided 51 entrants, of whom 31 passed. A Register of Students preparing for the examination has now been opened. The Council acknowledge with appreciation the very great service rendered by the Association of Principals of Technical Institutions, which has made very valuable recommendations regarding the development of the examination scheme which are likely to prove of far-reaching importance.

Visits and Social Functions.

The number of visits and social functions held by our various local sections is growing steadily. All have been well supported, showing that members appreciate this expansion.

International Management Congress.

The Institution was officially represented at the Sixth International Management Congress held in London this summer, and several members took part in the proceedings. The paper from this country on "Production Management Technique" was contributed by Mr. C. R. F. Englebach, M.I.P.E. This subject was discussed by several of our Sections during the recent session.

Standardisation.

The Standards Committee of the Institution is now in being, under the Chairmanship of Mr. H. A. Hartley. It includes among its members a representative of the British Standards Institution.

Thanks to Lecturers.

The Council extends a sincere and hearty vote of thanks to all lecturers, members and others, whose work forms so large a part of the major activity on which the Institution depends. Over one hundred lectures have now to be provided each session, and to a large extent the prestige of the Institution hinges on the quality provided. During the past session about half of the lectures were given by members, but it is earnestly hoped that in future years the percentage of lectures given by members will be considerably higher.

The Work of the President.

In concluding this report, the Council places on record its appreciation of the services rendered to the Institution by Sir Walter Kent during the two years of his office as President, and is particularly pleased that his assistance and support is to be continued as a member of Council.

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